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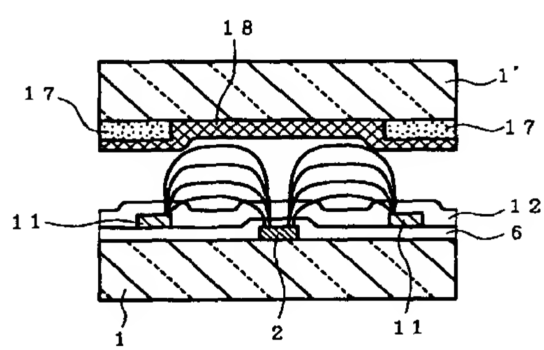
(54) Liquid crystal display device with wide viewing angle characteristics comprising a high resistivity black matrix

(57) The invention relates to a liquid crystal display device comprising a black mask (17) formed on one of two substrates (1, 1') at least one of which is transparent, a group of electrodes (2, 11) formed on at least one of the substrates (1, 1'), a liquid crystal layer comprising a liquid crystal composition (21) having a dielectric anisotropy and held between the substrates (1, 1'), an orientation control film (20, 20') formed between the liquid crystal layer and one or both of the substrates (1, 1') for orienting the liquid crystal molecules of the liquid crystal composition in a predetermined direction, polarizing means (13, 13') laminated on at least one of the two substrates (1, 1') and driving means for applying a drive voltage to the group of electrodes (2, 11) wherein the group of electrodes (2, 11) has such a structure that an electric field having a component predominantly in parallel with the interface between the orientation control film (20, 20') and the liquid crystal layer is generated, the liquid crystal composition has a resistivity of not smaller than $10^N\ \Omega\cdot$cm, and the black mask (17) has a resistivity of not smaller than $10^M\ \Omega\cdot$cm, wherein N and M are integers satisfying the conditions $N > 9$ and $M > 6$.

Thereby, the light-shielding ability of the black mask (17) is practically satisfactory, a disturbance of the electric field pattern is eliminated, and color displays of high quality without color nonuniformity can be achieved.

FIG. 4



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Description

Background of the Invention

Field of the Invention

The present invention relates to a liquid crystal display device and, particularly, to an active matrix liquid crystal display device of a high picture quality with wide viewing angle characteristics comprising a high resistivity black matrix and with excellent light-shielding ability.

Description of the Prior Art

Display devices using a liquid crystal display device having reduced thickness and reduced weight and consuming decreased amounts of electric power have in recent years been widely used for personal computers, word processors and other information equipment.

Basically, the liquid crystal display device has a matrix made up of a number of electrodes arranged horizontally and vertically and a liquid crystal layer interposed between the horizontal electrodes and the vertical electrodes, and pixels are formed at the portions where two electrodes intersect each other to display a two-dimensional picture.

The liquid crystal display devices of this kind can be divided into those of a so-called passive matrix system which selects a predetermined pixel at a timing of a pulse applied to horizontal and vertical electrodes, and those of a so-called active matrix system in which a non-linear element such as a transistor or the like is provided in each pixel and a predetermined non-linear element is selected.

In a liquid crystal display device of the active matrix system, non-linear elements (switching elements) are provided at positions corresponding to a plurality of pixel electrodes arranged in the form of a matrix. Theoretically, the liquid crystal in each pixel can be driven at all times (duty ratio of 1.0). Compared with the so-called passive matrix system employing a time-division multiplex driving system, therefore, the active matrix system exhibits a good contrast and represents a technique that is indispensable particularly in color liquid crystal display devices. Thin-film transistors (TFTs) are representative examples of the switching elements.

In a conventional thin-film transistor liquid crystal display element, transparent electrodes are so formed as to face each other on the interface of two substrates to drive the liquid crystal layer.

That is, there has been employed a display system as represented by a so-called twisted nematic display system in which the direction of the electric field applied to the liquid crystal is almost perpendicular to the interface of the substrates owing to the employment of the above-mentioned electrode structure.

As a system in which the direction of an electric field applied to the liquid crystals is almost in parallel with the interface of the substrates, furthermore, there has been proposed a system (so-called in-plane electric field system) employing a pair of comb-shaped electrodes formed on the surface of at least one of the substrates for driving the liquid crystal layer, as disclosed in, for example, the Japanese patent publication JP 21907/1988 and the Japanese patent application JP 36058/1995. The method of setting comb-shaped electrodes and the method of their fabrication have been proposed already by the present applicant in the Japanese patent application JP 105862/1995.

In such an electrode structure, the major axes of the molecules of the liquid crystal layer (hereinafter also referred to simply as liquid crystal molecules) are substantially in parallel with the surfaces of the substrates, and the liquid crystal molecules are suppressed from being erected in a direction perpendicular to the substrates. Therefore, the brightness changes little even when the viewing angle is changed; i.e., the so-called viewing angle dependence does almost not exist, and wide viewing angle characteristics are accomplished as compared with those of the vertical electric field system.

In a conventional black mask interposed among the colored layers of various colors and constituting the substrate of a color filter (color-filter substrate), furthermore, a pattern of a thin film of chromium metal or low-reflection chromium metal has been formed. Or, a pattern of a thin layer made of a photosensitive resin has been formed, wherein a black coloring agent, or black carbon powder (chiefly graphite) are dispersed, with addition of various pigments thereto.

The colored layers of the color-filter substrate usually have a structure in which (cf. Fig. 7) a protective layer PSV2 is formed on the colored layers FIL(R), FIL(G), FIL(B) of which the pattern regions are separated like a mosaic or vertical stripes for each of the pixels or colors.

When the colored layers are fabricated by using resin materials comprising a dispersed pigment in the color filter used for the active matrix-type liquid crystal display devices, furthermore, the protective layer PSV2 is not often employed.

Fig. 13 is a schematic sectional view illustrating the structure of a pixel that constitutes an in-plane electric field-type liquid crystal display device, and illustrating the turn-on operation. The structure comprises a TFT substrate 1, a color-filter substrate 1', a common electrode 2, an insulating film 6, pixel electrodes 11, a protective film 12, a black mask 17 and a color filter 18.

In Fig. 13, a liquid crystal layer is held between the TFT substrate 1 and the color filter substrate 1'. On the surfaces of the protective film 12 and of the color filter 18 are formed orientation films for establishing the initial orientation of liquid crystal molecules of the liquid crystal layer. Moreover, though not shown in Fig. 13, polarizer plates are installed on the outer surface sides of the TFT substrate 1 and the color filter substrate 1'.

In the above mentioned in-plane electric field liquid crystal display device, the pixel electrodes 11 and the common electrode 2 are formed on one substrate (TFT

substrate 1), and on the other substrate (color-filter substrate 1') is formed a color filter 18 that constitutes a color of a pixel demarcated by the black mask 17.

The black mask 17 demarcating the color filter prevents the reflection of external light and enhances the contrast by absorbing light from the neighboring pixels.

Summary of the Invention

In a conventional vertical electric field liquid crystal display device having a common electrode formed on the side of the color-filter substrate, the black mask constituting the color-filter substrate is required to have a high light absorption factor and a low light reflection factor. However, no consideration concerning the resistivity of the black mask has been taken.

That is, in the above-mentioned black mask using a resin material, a large amount of graphite is added particularly to improve the absorption factor. Therefore, the resistivity decreases with an increase in the amount of graphite added. When metallic chromium is used for the black mask, furthermore, the light-shielding ability is improved greatly, and the resistivity becomes very small.

In the in-plane electric field-type liquid crystal display device in which the black mask has a small resistivity, however, the lines of electric force from the pixel electrodes 11 are attracted by the black mask 17 having a small resistivity, as shown in Fig. 13, when a voltage is applied between the pixel electrodes 11 and the common electrode 2 to turn the pixel on, and the pattern of the electric field is disturbed and tilted with respect to the interface of the substrates. As a result, the horizontal component of the lines of electric force is weakened, and a desired light transmission factor is not obtained. Alternatively, so-called domains occur at positions of the pixel electrodes 11 and the common electrode 2. Accordingly, the contrast is degraded, the color display becomes nonuniform, and a good picture quality is not obtained.

Figs. 14A and 14B are schematic diagrams illustrating a pixel in an in-plane electric field liquid crystal display device having two comb-shaped common electrodes arranged in a pixel. Fig. 14A is a plan view, and Fig. 14B is a sectional view cut along the line A-A' in Fig. 14A. A color filter is formed on a portion surrounded by the black mask 17, and various films are formed thereon and on the common electrodes 2 and on the pixel electrodes 11, which, however, are not shown here.

In Figs. 14A and 14B, a pixel is formed in an open region surrounded by the black mask, a pixel electrode 11 and a common electrode 2 are arranged in this region, and a liquid crystal layer is held between the TFT substrate 1 and the color filter substrate 1'. The black mask has a resistivity of not larger than 10^4 $\Omega \cdot cm$.

By a signal voltage applied for turning on, an electric field is generated between the common electrode 2 and the neighboring pixel electrode 11. This electric field acts strongly upon the liquid crystal molecules depending upon the magnitude of the applied signal voltage, whereby the orientation of the liquid crystal molecules is rotated, and light passes from the TFT substrate 1 to the color-filter substrate 1' at an increased transmission factor.

Fig. 15 is a diagram illustrating the transmission factor that varies depending upon the position in the gap between the common electrode 2 and the pixel electrode 11 shown in Fig. 14A, wherein a spot a denotes a position away from the black mask 17 and a spot b denotes a position close to the black mask 17.

As shown, the transmission factor increases with an increase in the signal voltage applied between the common electrode 2 and the pixel electrode 11. As shown in Fig. 14A, however, since the spot b is located close to the black mask 17, the electric field pattern forms a sharp angle with respect to the surface of the substrate. Accordingly, regarding the change in the transmission factor with an increase in the signal voltage, the rise is behind that of the spot a. In Fig. 15, the signal voltage of the spot b must be increased by about one volt with respect to the spot a to obtain the same transmission factor.

When the same voltage is applied, therefore, the transmission factor differs between the central portion and the peripheral portion in a pixel, and the color becomes nonuniform.

The object of the present invention is to provide a liquid crystal display device particularly a so-called in-plane electric field device, having an improved light-shielding ability, suppressing a disturbance of the pattern of the electric field, and displaying pictures of high quality without nonuniformity in the color.

The above underlying problem is solved acccording to claim 1. The dependent claims relate to preferred embodiments of the concept of the present invention.

The concept of the present invention is not limited to the so-called in-plane electric field display devices, however, it is optionally applicable thereto.

The liquid crystal display device of the present invention comprises a black mask formed on one of a pair of substrates at least one of which is transparent, a group of electrodes formed on at least one of the two substrates, a liquid crystal layer comprising a liquid crystal composition having a dielectric anistropy and held between the two substrates, an orientation control film formed between the liquid crystal layer and one or both of the substrates for orienting the liquid crystal molecules of the liquid crystal composition in a predetermined direction, polarizing means laminated on at least one of the two substrates, and driving means for applying a drive voltage to the group of electrodes, wherein the liquid crystal composition has a resistivity of not smaller than 10^N $\Omega \cdot cm$, and the black mask has a resistivity of not smaller than 10^M $\Omega \cdot cm$, wherein N and M are integers satisfying the conditions $N > 9$ and $M > 6$.

In accordance with a preferred embodiment of the

present invention, the liquid crystal display device is a so-called in-plane electric field display device wherein the group of electrodes has such a structure that an electric field having a component predominantly in parallel with the interface between the orientation control film and the liquid crystal layer is generated.

In accordance with another preferred embodiment, the liquid crystal display device of the present invention comprises a liquid crystal composition which has a resistivity of not smaller than 10^N $\Omega \cdot$cm, and a black mask which has a resistivity of not smaller than 10^M $\Omega \cdot$cm, wherein N and M are integers satisfying the conditions $N > 13$ and $M > 7$.

According to another preferred embodiment, metal oxide particles are contained in the black mask.

In accordance with still another preferred embodiment, the metal oxide particles are particles of at least one metal oxide selected from cobalt oxide, chromium oxide, manganese oxide and nickel oxide.

A further preferred embodiment is characterized in that an organic pigment and/or a graphite powder are contained in the black mask in addition to the metal oxide particles.

Another preferred embodiment is characterized in that the cobalt oxide particles are chiefly tricobalt tetroxide particles. In accordance with still a further preferred embodiment, the black mask contains particles of chromium oxide, manganese oxide and/or nickel oxide in addition to cobalt oxide particles.

The black mask preferably contains a polyimide resin as base material.

The base material of the black mask is preferably a resin material having polyimide groups, the composition of the resin material containing a component that is cured by light and a component that is cured by heat, and the optical density increasing as the resin material is cured by heat.

The black mask is preferably composed of a polyimide resin material which contains at least one or more kinds of black coloring agents and other coloring agents different from the black coloring agents.

Furthermore, according to a preferred embodiment, the black mask is composed of a polyimide resin material in which metal oxide particles are mixed or dispersed as black coloring agent.

In the display device of the present invention, the black matrix formed on at least one of the pair of substrates shuts off the entry of light from the neighboring pixels that are turned on, thus contributing to increasing the contrast of a display image.

In accordance with a preferred embodiment, the group of electrodes formed on one or both of the pair of substrates comprises a common electrode and a pixel electrode, and forms an electric field pattern between the two electrodes when the pixel is turned on which leads to a rotation of the orientation of the liquid crystal molecules of the liquid crystal composition that constitutes the liquid crystal layer, so that the light transmission factor changes. The orientation control film (orientation film) works to orient the liquid crystal molecules of the liquid crystal composition in a predetermined direction when no electric field is applied.

The polarizing means are laminated on at least one of the pair of substrates, and permit the passage of light that is polarized in a specific direction before entering into the liquid crystal layer or after having passed through the liquid crystal layer.

The driving means apply a drive voltage to the group of electrodes to turn a predetermined pixel on to display an image.

The group of electrodes preferably has a structure wherein the electrodes are so arranged as to generate an electric field having a component predominantly in parallel with the interface between the orientation control layer and the liquid crystal layer. When the electric field is generated between the common electrode and the pixel electrode constituting the group of electrodes, the liquid crystal molecules are rotated in a plane substantially in parallel with the interface.

The liquid crystal composition has a resistivity of not smaller than 10^N $\Omega \cdot$cm and the black mask has a resistivity of not smaller than 10^M $\Omega \cdot$cm (where N and M are integers), satisfying the conditions $N > 9$ and $M > 6$, thereby to effectively generate an electric field component in parallel with the substrates.

Accordingly, the liquid crystal molecules are rotated in a plane substantially in parallel with the interface, making it possible to suppress the occurrence of so-called domains and the rise of the drive voltage.

In accordance with one of the above-indicated preferred embodiments, the liquid crystal composition has a resistivity of not smaller than 10^N $\Omega \cdot$cm, and the black mask has a resistivity of not smaller than 10^M $\Omega \cdot$cm (where N and M are integers), satisfying the conditions $N > 13$ and $M > 7$, thereby to more effectively generate an electric field component in parallel with the substrates than in the general case of $N > 9$ and $M > 6$.

Accordingly, the liquid crystal molecules are rotated in a plane substantially in parallel with the interface, making it possible to further suppress the occurrence of so-called domains and the rise of the drive voltage.

In the case of the presence of metal oxide particles in the black mask and of in-plane electric field devices, the black mask exhibits an increased resistivity yet maintaining an optical density, and the electric field component is more effectively generated between the electrodes in a plane nearly in parallel with the above-mentioned interface.

Accordingly, the liquid crystal molecules are rotated in a plane nearly in parallel with the interface, making it possible to suppress the occurrence of so-called domains and the rise in the drive voltage, and enabling the light transmission factor to be improved.

The use of cobalt oxide particles, chromium oxide particles, manganese oxide particles or nickel oxide particles in the black mask leads to an increased optical density and an increased resistivity of the mask. Therefore, the electric field component is generated more

effectively between the electrodes in a plane in parallel with the above-mentioned interface.

Accordingly, the liquid crystal molecules are rotated in a plane nearly in parallel with the interface, making it possible to further suppress the occurrence of so-called domains and the rise of the drive voltage, and enabling the light transmission factor to be further improved.

A further improvement may be achieved when the black mask contains an organic pigment and/or a graphite powder in addition to the metal oxide particles. This leads to further increased resistivity and still more efficient light absorption of the black mask. Accordingly, the liquid crystal molecules are rotated in a plane nearly in parallel with the interface, making it possible still further suppress the occurrence of so-called domains and the rise of the drive voltage, and enabling the light transmission factor to be still further improved.

Preferably, tricobalt tetroxide is chiefly used for the cobalt oxide particles; thus, the black mask maintains its resistivity and absorbancy.

A further improvement can be achieved by the use of chromium oxide, manganese oxide and/or nickel oxide in addition to the cobalt oxide. In that case, the black mask maintains its resistivity and light absorption factor.

The base material of the black mask is preferably made of a polyimide photosensitive resin, and a feature that the optical density increases in the step of curing the resin by light and heat is utilized in order to obtain a black mask of nearly black color having a high insulating property.

Therefore, according to a preferred embodiment, the black mask is comprised of a material which contains a polyimide resin as the base material and has a high resistivity. Therefore, the insulating property is prevented from decreasing, and the electric field component for rotating the liquid crystal molecules is effectively generated in parallel with the interface.

In the preferred case where the black mask is made of a resin material having polyimide groups and containing a component that is cured by light and a component that is cured by heat, there is formed a black mask that is colored in black upon the curing by heat, and exhibits a great light-shielding ability.

In accordance with still a further preferred embodiment, the black mask is made of a polyimide resin material that contains one or more kinds of black coloring agents and other coloring agents than the above-mentioned black coloring agents. Therefore, the black mask exhibits a great light-shielding ability.

Corresponding to a further preferred embodiment, the black mask is made of the polyimide resin material in which metal oxide particles are mixed or dispersed as black coloring agent. Thus, the black mask exhibits a high resistivity and a great light-shielding ability.

The above-mentioned polyimide-type photosensitive resin has in the molecule skeleton thereof a functional group that absorbs visible light rays but does not contain carbon or graphite which have been conventionally used therein. It is therefore possible to set a low transmission factor without lowering the resistivity.

The foregoing and other objects, advantages, manner of operation and novel features of the present invention will be still better understood from the following detailed description in connection with the accompanying drawings.

Brief Description of the Drawings

Figs. 1A to 1D are schematic sketches of a pixel for explaining the operation of an in-plane electric field-type liquid crystal display device;

Figs. 2A to 2C are sketches illustrating the structure of a TFT substrate constituting an embodiment of an in-plane electric field liquid crystal display device;

Fig. 3 is a picture illustrating example 1 or 2 of the structure of a color-filter substrate in an in-plane electric field liquid crystal display device;

Fig. 4 is a schematic representation of an electric field pattern in a pixel in cross section constituting the embodiment 1 or 2 of the in-plane electric field liquid crystal display device;

Fig. 5 is a diagram illustrating the dependence of the drive voltage on the resistivity of the black mask (BM) when the resistivity of the liquid crystal layer of the in-plane electric field liquid crystal display device is changed;

Fig. 6 is a diagram illustrating the change in the resistivity of the black mask in dependence of the content of carbon therein and the change in the optical density when the film thickness is 1 μm, in the embodiment 1 of the present invention;

Fig. 7 is a sectional view illustrating an essential portion of the color-filter substrate used in the embodiment 3 of an in-plane electric field color liquid crystal display device;

Fig. 8 is a schematic representation illustrating the steps of forming the black mask shown in Fig. 7;

Fig. 9 is a diagram illustrating the steps of fabricating the color-filter substrate shown in Fig. 7;

Fig. 10 is a schematic representation showing the connection of an equivalent circuit of a display matrix unit and the peripheral circuits in a liquid crystal display device;

Fig. 11 is an exploded perspective view illustrating an example of the constitution of the liquid crystal display device according to the present invention;

Fig. 12 is a representation showing the appearance of a personal computer for explaining an information processing device in which a liquid crystal display device of the present invention is used;

Fig. 13 is a schematic sectional view for illustrating the constitution of a pixel constituting an in-plane electric field liquid crystal display device and for illustrating the turn-on operation;

Figs. 14A and 14B are schematic views of a pixel in an in-plane electric field liquid crystal display device in which two comb-shaped common electrodes are arranged in a pixel, and

Fig. 15 is a diagram illustrating the change in the transmission factor depending upon the position in the gap between the pixel electrode and the common electrode shown in Figs. 14A and 14B.

Description of Preferred Embodiments

Embodiments of the present invention will now be described in detail with reference to the drawings.

Figs. 1A to 1D are schematic representations of a pixel for explaining the operation of a liquid crystal display device to which the present invention is applied. Fig. 1A is a sectional view of the structure when no voltage is applied, Fig. 1B is a sectional view of the structure when a voltage is applied, Fig. 1C is a plan view of the structure when no voltage is applied, and Fig. 1D is a plan view of the structure when a voltage is applied. The voltage referred to here is a selection voltage applied between the common electrode and the pixel electrode.

The device of Figs. 1A and 1B comprises transparent glass substrates 1 and 1' (hereinafter also referred to simply as substrates), common electrode 2, an insulating film 6, a signal wiring 10, a pixel electrode 11, a protective film 12, polarizer plates 13 and 13', where the axes of polarization of the polarizer plates are denoted by 14 and 14', the orientation of the liquid crystal molecules is denoted by 15, and the direction of the electric field is denoted by 16. The devices further comprises a black mask (BM), a color filter 18, a protective film 19 (flattening film), orientation films 20 and 20' and liquid crystal molecules 21 (chiefly rod-like liquid crystal molecules).

The liquid crystal display device comprises the polarizer plate 13', a black mask 17 for shielding light, a color filter 18, a protective film 19 and an orientation film 20' that are formed on one substrate (color-filter substrate 1') of two transparent glass substrates 1 and 1'. On the other substrate (TFT substrate) 1 are formed the polarizer plate 13, the orientation film 20 facing the liquid crystal 21, a signal electrode 10, a pixel electrode 11, a common electrode 2, wirings and a thin-film transistor (TFT). Figs. 1A and 1B do not illustrate the wiring or the structure of the thin-film transistors.

Referring to Figs. 1A and 1C, the liquid crystal molecules 21 are oriented homogeneously by the orientation films 20, 20' in the direction 15 of orientation which is nearly in parallel with the planes of the substrates 1, 1'. In this state, the direction of initial orientation of the liquid crystal molecules 21 is nearly in agreement with the axis 14 of poarization of the polarizer plate 13, and the axis 14' of polarization of the upper polarizer plate 13' is perpendicular thereto, and the pixel is in a non-display (turned-off) state.

Referring next to Figs. 1B and 1D, a voltage is applied between the common electrode 2 and the pixel electrode 11 formed on the substrate 1 to form an electric field (direction 16 of the electric field) in a direction nearly in parallel with the interface of the substrates 1, 1'. Then, the liquid crystal molecules 21 are oriented and rotated in a plane nearly in parallel with the interface of the substrates 1, 1'. Accordingly, the pixel is placed in a display (turned-on) state. A large number of pixels are arranged to constitute a display device.

Figs. 2A to 2C are representations illustrating the structure of a TFT substrate which constitutes a liquid crystal display device of an embodiment of the present invention, wherein Fig. 2A is a plan view, Fig. 2B is a sectional view taken along the line A-A' of Fig. 2A, and Fig. 2C is a sectional view taken along the line B-B' of Fig. 2A.

In Figs. 2A to 2C, the same reference numerals as those of Figs. 1A to 1D denote the same portions. The structure further comprises a common wiring 3, a scanning electrode 4, a scanning wiring 5, an insulating film 6, a semiconductor layer 7, a thin-film transistor portion 8 (TFT portion), a signal wiring 10, pixel electrodes 11 and a protective film 12.

The scanning electrode 4, the scanning wiring 5, the common electrodes 2 and the common wiring 3 are provided in the same layer and are made of the same material. The semi-conductor layer 7 is formed via the thin layer and the insulating film 6, and the signal wiring 10 and the pixel electrode 11 are formed in the same layer using the same material.

Part of the pixel electrode 11 is so arranged as to overlap with the common wiring 3 in a direction perpendicular to the surface of the substrate via the insulating film 6, creating a capacitance to hold a signal voltage that is applied between the pixel electrode 11 and the common electrode 2.

Fig. 3 is a representation illustrating an example of the structure of the color-filter substrate constituting the liquid crystal display device according to the embodiment 1 of the present invention, wherein the same reference numerals as those of Figs. 1A to 1D denote the same portions.

As shown in Fig. 3, the color filter substrate has a plurality of color filters (R, G, B) demarcated by the black mask 17 on one surface of the transparent substrate 1', and further has the protective film (smoothing layer) 19 and the orientation film 20', formed thereon. The polarizer plate 13' is deposited on the other surface

of the transparent substrate 1'.

When the liquid crystal layer has a resistivity of not smaller than 10^N $\Omega \cdot cm$, the black mask 17 demarcating a plurality of color filters R, G and B must have a resistivity of not smaller than 10^M $\Omega \cdot cm$, satisfying the conditions $N > 9$ and $M > 6$, where N and M are integers.

When the liquid crystal layer and the black mask have such resistivities, the electric field pattern formed by the selection voltage applied between the common electrode and the pixel electrode has an effectively increased component nearly in parallel with the interface between the liquid crystal layer and the orientation film, and makes it possible to suppress the rise of the drive voltage. Furthermore, the occurrence of domains is greatly decreased, and a high-contrast display is obtained.

Fig. 4 is a sectional view schematically illustrating an electric field pattern of a pixel that constitutes the liquid crystal display device of the embodiment 1 according to the present invention, wherein the lines of electric force generated between the common electrode 2 and the pixel electrodes 11 are not affected by the black mask 17, the electric field pattern is nearly in parallel with the interface between the liquid crystal layer and the orientation film, occurrence of domains is greatly decreased at the positions of the pixel electrodes 11 and at the position of the common electrodes 2, the transmission factor is enhanced in the open region of the pixel, and a high-contrast display is obtained.

The same effects are produced even when the liquid crystal layer has a resistivity of not smaller than 10^N $\Omega \cdot cm$ and the black mask has a resistivity of not smaller than 10^M $\Omega \cdot cm$ (N and M are integers), satisfying the relationships $N > 13$ and $M > 7$.

In embodiment 1, the material of the black mask is blended with a mixture of an organic pigment and carbon; i.e., the amount of carbon is adjusted so that the above-mentioned desired resistivity is obtained.

Fig. 5 is a diagram illustrating the drive voltage relative to the resistivity of the black mask of when the resistivities of the liquid crystal layer and of the black mask of the aforementioned embodiment 1 are changed.

In Fig. 5, assuming that the allowable value of drive voltage increase relative to the allowable value of transmissivity change, which s hould be less than one gray scale level, is not larger than 0.1 volt, the resistivity of the black mask must be higher than 3×10^6 $\Omega \cdot cm$ when the liquid crystal has a resistivity of 10^9 $\Omega \cdot cm$, and the resistivity of the black mask must be higher than 5×10^7 $\Omega \cdot cm$ when the liquid crystal has a resistivity of 10^{13} $\Omega \cdot cm$.

From these facts, the aforementioned effects are obtained by determining the values M and N satisfying the relationships $N > 9$ and $M > 6$ or $N > 13$ and $M > 7$.

When the black mask contains carbon, the resistivity decreases with an increase in the amount of carbon that is contained and increases with a decrease in the amount of carbon. An increase in the amount of carbon results in an increase in the optical density (hereinafter referred to as OD value). However, since carbon is electrically conductive, it decreases the resistivity.

That is, the amount of carbon must be so set as to satisfy the above-mentioned mutually conflicting requirements.

Fig. 6 is a diagram illustrating a relationship between the resistivity change of the black mask depending upon the amount of carbon and the OD value of the black mask of when the film thickness is 1 μm, wherein curve a represents the resistivity of the black mask, and curve b represents the OD value.

In Fig. 6, the abscissa represents the amount of carbon (relative value) in the black mask, the ordinate of the left side represents the resistivity ($\Omega \cdot cm$) of the black mask and the ordinate of the right side represents the OD value of when the film thickness is 1 μm.

From the relationship between the resistivity that varies depending upon the amount of carbon and the optical density (OD value) shown in Fig. 6, it is understood that the resistivity of the black mask becomes not smaller than 10^6 $\Omega \cdot cm$ when the relative amount of carbon is about 50, and the OD value can be determined to be more than 1.6 which is practically satisfactory.

As described earlier, the material of the black mask contains a mixture of organic pigment and carbon, and the mixing ratio of carbon is adjusted to accomplish the resistivity that lies within the above-mentioned range. The present invention, however, is in no way limited thereto only but a desired resistivity can be accomplished by using other light-absorbing materials.

That is, in another embodiment 2 as shown in Fig. 3, the black mask 17 demarcating a plurality of color filters R, G, B can be formed by a known lithographic method by using a resist that contains particles of a tricobalt tetroxide (Co_3O_4) as particles of cobalt oxide.

It is further possible to use a resist that contains tricobalt tetroxide and either or both of an organic pigment and carbon (chiefly graphite).

It is further possible to use a resist containing any one of chromium oxide, manganese oxide and nickel oxide.

The mixing ratio of the components of the resist is so adjusted that the black mask 17 has a resistivity of not smaller than 10^6 $\Omega \cdot cm$.

Since the metal oxide particles such as cobalt oxide particles are contained in the black mask, the light absorption factor can be further increased, maintaining a large resistivity of the black mask. Then, the liquid crystal molecules rotate in a plane nearly in parallel with the interface, making it possible to suppress the occurrence of so-called domains and the rise of the drive voltage and enabling the light transmission factor to be enhanced.

Fig. 7 is a sectional view illustrating an essential portion of the color-filter substrate used in a further embodiment 3.

The color filters of Fig. 7 have the black mask BM

made of a polyimide-type resin and formed on the glass substrate SUB2; i.e., color filters (pixels) FIL(R), FIL(G) and FIL(B) demarcated by the black mask BM are provided.

Fig. 8 is a diagram schematically illustrating the steps of forming the black mask shown in Fig. 7, wherein PBM denotes a polyimide photosensitive resin film, MSIC denotes a photomask for exposing the black mask, hv denotes ultraviolet rays, and BM' denotes a black mask pattern.

The above-mentioned polyimide photosensitive resin is, for example, a photosensitive polyimide resin Ddp-1120(s)(trade name) manufactured by Nitto Denko Corp.

In Fig. 8, a glass substrate SUB2 that serves as a color-filter substrate is prepared (step A), and a polyimide photosensitive resin film PBM is uniformly applied onto the glass substrate SUB2 by a spin-coating method (step B).

The polyimide photosensitive resin film PBM is prebaked at about 70°C for about 15 minutes and is dried.

Next, ultraviolet rays hv are applied via a photomask MSK having openings corresponding to the pattern of arrangement of black masks (step C). Here, the energy for the exposure is about 500 mJ/cm^2. Due to the exposure, the portions irradiated with ultraviolet rays undergo the crosslinking reaction and the resin is cured.

After the exposure, the polyimide photosensitive resin film PBM is heat-treated in an oven at 180°C for 10 minutes or on a hot plate 180°C for two minutes. Due to the heat-treatment, the density of the polyimide photosensitive resin film PBM increases and the film PBM exhibits increased light-shielding ability.

After the heat-treatment, the polyimide photosensitive resin film PBM is developed with a developing solution to remove the portions that are not irradiated with ultraviolet rays, whereby a black mask pattern BM' made of the polyimide resin is formed (step D).

Finally, the black mask pattern BM' is cured at 350°C to 400°C for about one hour to form the black mask BM (step E).

The processing conditions in the above-mentioned steps are merely examples and can be changed depending upon the thickness of the film that is applied and the blackness that is required.

The polyimide resin film is blackened by being cured by heat in the step of heat-treatment after the exposure to light. The principle of blackening has been disclosed in Omote Toshihiko, Hayashi Shunnichi, Fujii Hirobumi, "Polymer Preprints, Japan", Vol. 41, No. 7, 1992, pp. 2836-2838.

As described earlier, the material constituting the black mask is the polyimide resin not containing electrically conductive material. Therefore, the black matrix exhibits a large resistance.

Then, the pixels (RGB) are formed. As required, furthermore, a flattening film or a protective layer is formed thereon to obtain a color-filter substrate.

In the inplane electric field liquid crystal element described earlier, the opposing electrodes are not required on the side of the color-filter substrate.

Next, a process for forming color filters of various colors on the color-filter substrate having a black mask formed by the above-mentioned processing will be described below.

Fig. 9 is a diagram illustrating the steps of producing the color-filter substrate used for the color liquid crystal display device according to the embodiment 3.

First, the black matrix is formed on the glass substrate, using the process explained with reference to Fig. 8.

The pattern of the black mask serves as a reference of the whole dimensional precision and for forming the color filters (pixels).

The thickness of the black mask is determined depending upon the optical properties thereof, i.e., depending upon the light-shielding ability. In the embodiment 3, the thickness of the black mask is about 1.0 to about 1.5 μm.

A red pigment-dispersed resin material is applied by spin-coating or the like method onto the substrate on which the black mask has been formed, and is exposed to ultraviolet rays via an exposure mask having an opening corresponding to the red filter. The material is developed to leave the exposed portions, cured and dried by postbaking to form a red filter FIL(R).

Next, a green pigment-dispersed resin material is applied by spin-coating or the like method, and is exposed to ultraviolet rays via an exposure mask having an opening corresponding to the green filter. The material is developed to leave the exposed portions, cured and dried by postbaking to form a green filter FIL(G).

Similarly, a blue pigment-dispersed resin material is applied by spin-coating or the like method, and is exposed to ultraviolet rays via an exposure mask having an opening corresponding to the blue filter. The material is developed to leave the exposed portions, cured and dried by postbaking to form a blue filter FIL(B).

Through these steps, color filters of three colors demarcated by the black mask BM are formed.

According to the embodiment 3, the black mask formed among the pixels exhibit a high light absorption factor, making it possible to provide a color liquid crystal display device having an excellent contrast and a high reliability.

In this embodiment, when the black mask has a resistivity of not smaller than 10^7 $\Omega \cdot$cm, a coloring agent may be added to the color-filter material to control the transmission factor.

The coloring agents to be added to the resin-type black mask material may be graphite, carbon, red, green and blue pigments,or metal oxide particles.

Among the above-mentioned coloring agents, pigments have little electrical conductivity. Therefore, addition of the pigments makes it possible to compensate for low absorption factor among the spectral characteristics of the polyimide-type resin.

An increase in the amount of graphite or carbon to increase the light-shielding ability results in an increase in the electric conductivity. Therefore, limitation is imposed on the amount of their addition.

The amount of addition, however, also varies depending upon the resistance of the resin that is used, the resistance of the material that is added, and the size (particle diameter).

In particular, graphite and carbon have high light-shielding ability and are preferable for increasing the OD (optical density) value.

As the black coloring agent, furthermore, use is made of metal oxide particles such as of the aforementioned cobalt oxide, chromium oxide, manganese oxide or nickel oxide, thereby to form a black mask that exhibits a high light absorption factor, a light-shielding ability and a high resistivity.

According to the embodiment 3 as described above, the color-filter substrate is fabricated by using the polyimide photosensitive resin to provide a color liquid crystal surface having a high contrast.

A more specific constitution of the present invention will be described.

Fig. 10 is a diagram illustrating the connection of an equivalent circuit of a display matrix unit in the liquid crystal display device of the present invention and the peripheral circuits.

In Fig. 10, symbol AR denotes a matrix array in which a plurality of pixels are two-dimensionally arranged, X denotes drain lines DL, and subscripts G, B, R denote pixels of green blue and red colors.

Symbol DTM denotes drain terminals, GTM denotes gate terminals, Y denotes gate lines GL, and subscripts 1, 2, 3, ---, end are in the order of the scanning timings. The gate lines Y (subscripts are omitted) are connected to a gate driver unit V.

The drain lines X (subscripts are omitted) are connected to a drain driver unit H arranged along one of the long sides of the display panel, and terminals are led out from one side only of the liquid crystal display panel like the gate lines Y.

SUP includes a power supply unit for obtaining stabilized voltages as basic gray-scale levels whose voltages are generated by dividing the voltage of a voltage supply, and a converter for converting information for the CRT (cathode-ray tube) from a host (host arithmetic unit) into information for the TFT liquid crystal display device.

Fig. 11 is an exploded perspective view illustrating the constitution of the liquid crystal display device according to the present invention, i.e., specifically illustrating the structure of the liquid crystal display device (hereinafter referred to as module in which the liquid crystal display panel, circuit board, backlight and other constituent members are combined as a unitary structure: MDL).

In Fig. 11, symbol SHD denotes a shielded case (also referred to as a metal frame) made of a metal plate, WD denotes a display window, INS1 to INS3 denote insulating sheets, PCB1 to PCB3 denote circuit boards (PCB1 is a circuit board on the drain side or a circuit board for drain driver, PCB2 is a circuit board on the gate side, PCB3 is an interface circuit board), JN1 to JN3 denote joiners for electrically connecting the circuit boards PCB1 to PCB3 together, TCP1 and TCP2 denote tape carrier packages, PNL denotes a liquid crystal display panel, GC denotes a rubber cushion, ILS denotes a light-shielding spacer, PRS denotes a prism sheet, SPS denotes a diffusion sheet, GLB denotes a light-guide plate, RFS denotes a reflection sheet, MCA denotes a lower case (molded frame) formed by one-piece molding, MO denotes an opening of the MCA, LP denotes a fluorescent lamp, LPC denotes a lamp cable, GB denotes a rubber bush for supporting the fluorescent lamp LP, BAT denotes a double-sided adhesive tape, and BL denotes a backlight comprising a fluorescent lamp , a light-guide plate and so on. Each part is stacked maintaining a relationship as shown thereby to assemble the liquid crystal display module MDL.

The liquid crystal display module MDL has two kinds of accommodating/holding members, i.e., a lower case MCA and a shielded case SHD. The metallic shielded case SHD accommodating and holding the insulating sheets INS1 to INS3, the circuit boards PCB1 to PCB3, and the liquid crystal display panel PNL is joined to the lower case MCA holding the backlight BL made up of the fluorescent lamp LP, the light-guide plate GLB, the prism sheet PRS and so on.

On the circuit board PCB1 for drain driver is mounted an integrated circuit chip for driving the pixels of the liquid crystal display panel PNL, and on the interface circuit board PCB3 are mounted an integrated circuit chip for receiving video signals from the external host and for receiving control signals such as timing signals, and a timing converter TCON for generating clock signals by processing timing signals.

The clock signals generated by the timing converter are fed to the integrated circuit chip mounted on the circuit board PCB1 for drain driver via a clock signal line CLL laid on the interface circuit board PCB3 and on the circuit board PCB1 for drain driver.

The interface circuit board PCB3 and the circuit board PCB1 for drain driver are multilayer wiring boards, and the clock signal line CLL is formed as an inner-layer wiring in the interface circuit board PCB3 and in the circuit board PCB1 for drain driver.

The circuit board PCB1 on the drain side for driving TFTs, the circuit board PCB2 on the gate side and the interface circuit board PCB3 are connected to the liquid crystal display panel PNL by tape carrier packages TCP1, TCP2, and the circuit boards are connected together by joiners JN1, JN2 and JN3.

The liquid crystal display panel PNL is an inplane electric field liquid crystal display device of the present invention, and the black mask formed on the color-filter substrate has a large resistivity so that an electric field pattern is formed between a pixel electrode and a common electrode almost in parallel with the interface of the

liquid crystal layer.

Fig. 12 is a diagram showing the appearance of a personal computer for explaining an information processing device having a liquid crystal display device of the present invention, wherein IV denotes an inverter power supply for driving a fluorescent lamp and CPU denotes a central processing unit on the host side.

As shown in Fig. 12, the personal computer equiped with the liquid crystal display device of the present invention has the circuit board for drain driver (circuit board for horizontal driver: circuit board on the drain side) PCB1 disposed at only the upper portion of the screen, leaving a margin in space on the lower side (keyboard side) of the display unit. Therefore, the space (hinge space) required to install hinges for coupling the keyboard unit and the display unit together can be small. This makes it possible to decrease the outer size of the display unit and, hence, to reduce the size of the personal computer as a whole.

According to the present invention as described above, the electric field created by the signal voltage in the so-called inplane electric field liquid crystal display device does hardly interfere with the black mask. Therefore, the electric field pattern formed by the selection voltage applied between the common electrode and the pixel electrodes is nearly in parallel with the interface between the liquid crystal layer and the orientation film, making it possible to suppress the rise of the drive voltage. Since the electric field pattern is not disturbed, the domains do not occur, and the liquid crystal display device has a high picture quality without nonuniformity in color.

The present invention is not limited to the liquid crystal display device of the TFT-type only but can be applied to the liquid crystal display devices of any other type inclusive of the active matrix type and the so-called simple matrix type.

In this embodiment, furthermore, the black mask is formed on one substrate side, and a group of electrodes are formed on the other substrate to generate an electric field nearly in parallel with the substrates. They, however, may be formed on the same substrate in compliance with the present invention, as a matter of course.

Claims

1. Liquid crystal display device, comprising a black mask (17) formed on one of a pair of substrates (1, 1') at least one of which is transparent, a group of electrodes (2, 11) formed on at least one of the two substrates (1, 1'), a liquid crystal layer comprising a liquid crystal composition (21) having a dielectric anisotropy and held between the two substrates (1, 1'), an orientation control film (20, 20') formed between the liquid crystal layer and one or both of the substrates (1, 1') for orienting the liquid crystal molecules of the liquid crystal composition in a predetermined direction, polarizing means (13, 13') laminated on at least one of the two substrates (1, 1') and driving means for applying a drive voltage to the group of electrodes (2, 11), wherein the liquid crystal composition has a resistivity of not smaller than $10^N\ \Omega \cdot cm$, and the black mask (17) has a resistivity of not smaller than $10^M\ \Omega \cdot cm$, wherein N and M are integers satisfying the conditions $N > 9$ and $M > 6$.

2. Liquid crystal display device according to claim 1, wherein the group of electrodes (2, 11) has such a structure that an electric field having a component predominantly in parallel with the interface between the orientation control film (20, 20') and the liquid crystal layer is generated.

3. Liquid crystal display device according to claim 1 or 2, wherein the liquid crystal composition substance has a resistivity of not smaller than $10^N\ \Omega \cdot cm$, and the black mask has a resistivity of not smaller than $10^M\ \Omega \cdot cm$, wherein N and M are integers satisfying the conditions $N > 13$ and $M > 7$.

4. Liquid crystal display device according to any of claims 1 to 3, wherein metal oxide particles are contained in the black mask (17).

5. Liquid crystal display device according to claim 4, wherein the metal oxide particles are particles of at least one metal oxide selected from cobalt oxide, chromium oxide, manganese oxide and nickel oxide.

6. Liquid crystal display device according to claim 4 or 5, wherein an organic pigment and/or graphite powder are contained in the black mask (17) in addition to the metal oxide particles.

7. Liquid crystal display device according to claim 5 or 6, wherein the cobalt oxide particles are mainly tricobalt tetroxide particles.

8. Liquid crystal display device according to any of claims 4 to 7, wherein the black mask (17) contains particles of chromium oxide, manganese oxide and/or nickel oxide in addition to cobalt oxide particles.

9. Liquid crystal display device according to any of claims 1 to 8, wherein the base material of the black mask (17) is made of a polyimide resin.

10. Liquid crystal display device according to claim 9, wherein the composition of the polyimide resin material contains a component that is cured by light and a component that is cured by heat, and the optical density of the black mask (17) is increased by the curing the resin material by heat.

11. Liquid crystal display device according to claim 9 or 10, wherein the black mask (17) is composed of a polyimide resin material which contains one or more kinds of black coloring agents and other coloring agents different from the black coloring agents.

12. Liquid crystal display device according to any of claims 9 to 11, wherein the black mask (17) is composed of a polyimide resin material in which metal oxide particles are dispersed as black coloring agent.

FIG. 1A

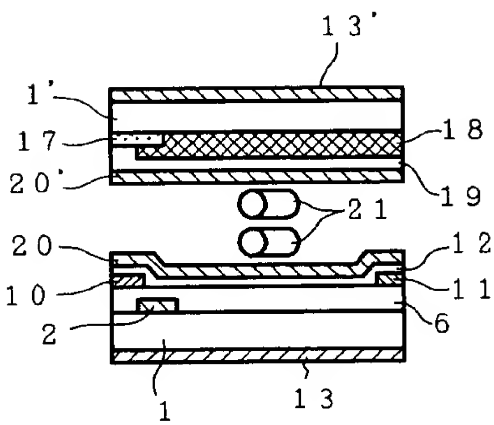


FIG. 1B

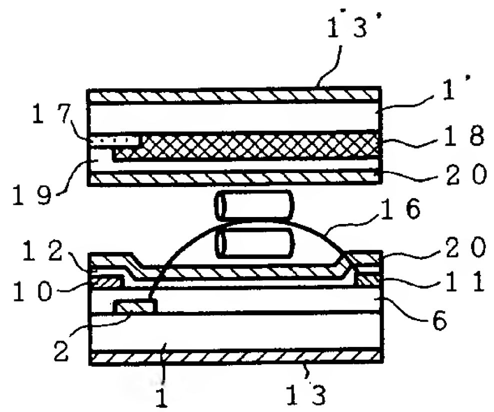


FIG. 1C

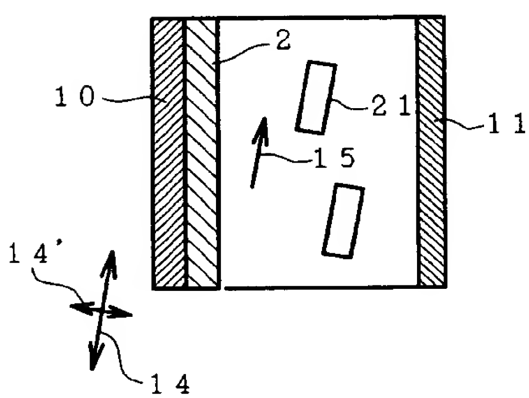


FIG. 1D

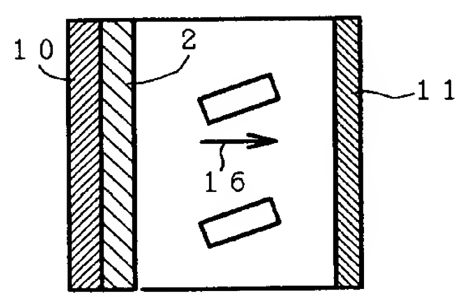


FIG. 2A

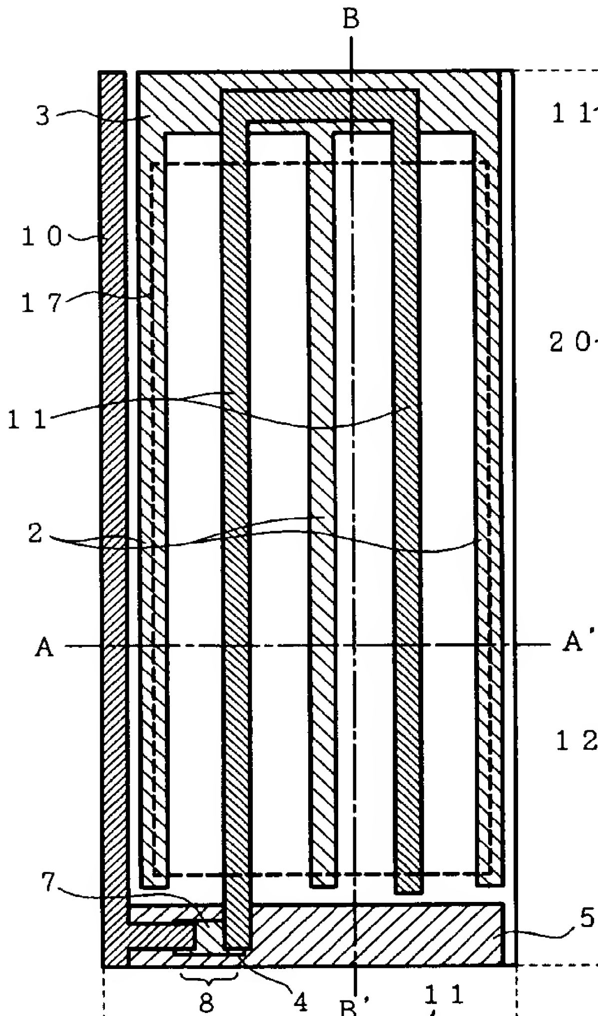


FIG. 2C

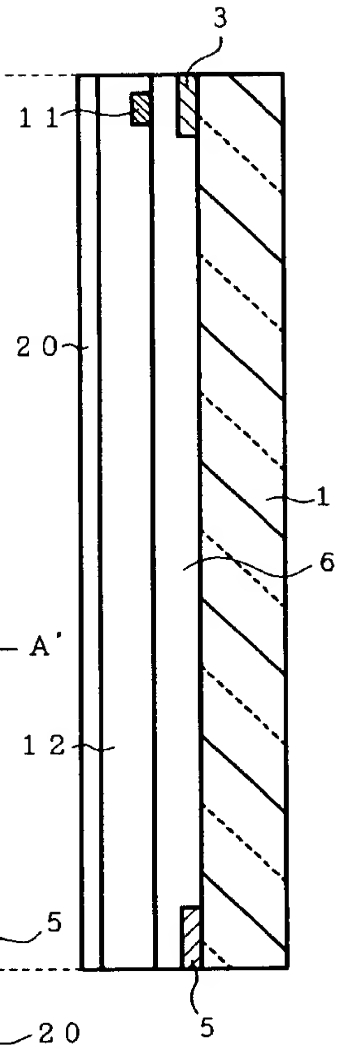


FIG. 2B

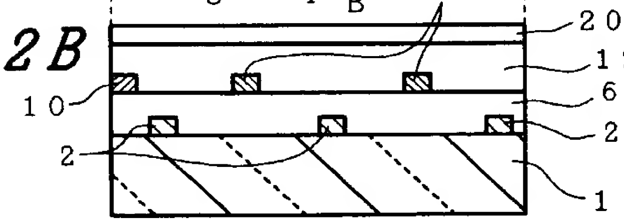


FIG. 3

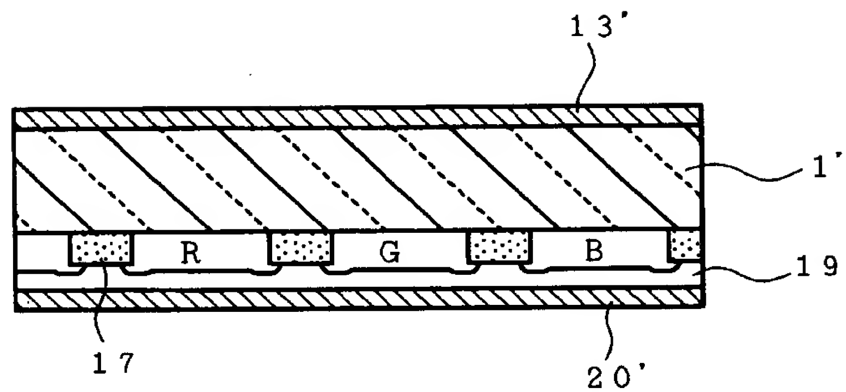


FIG. 4

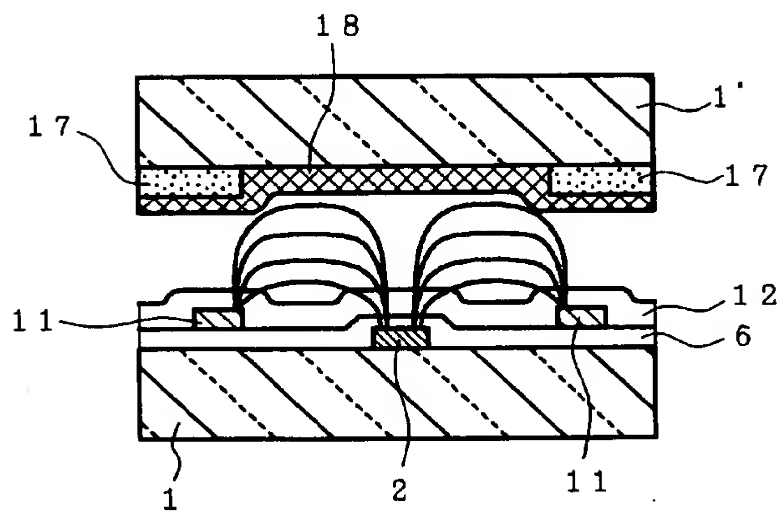


FIG. 5

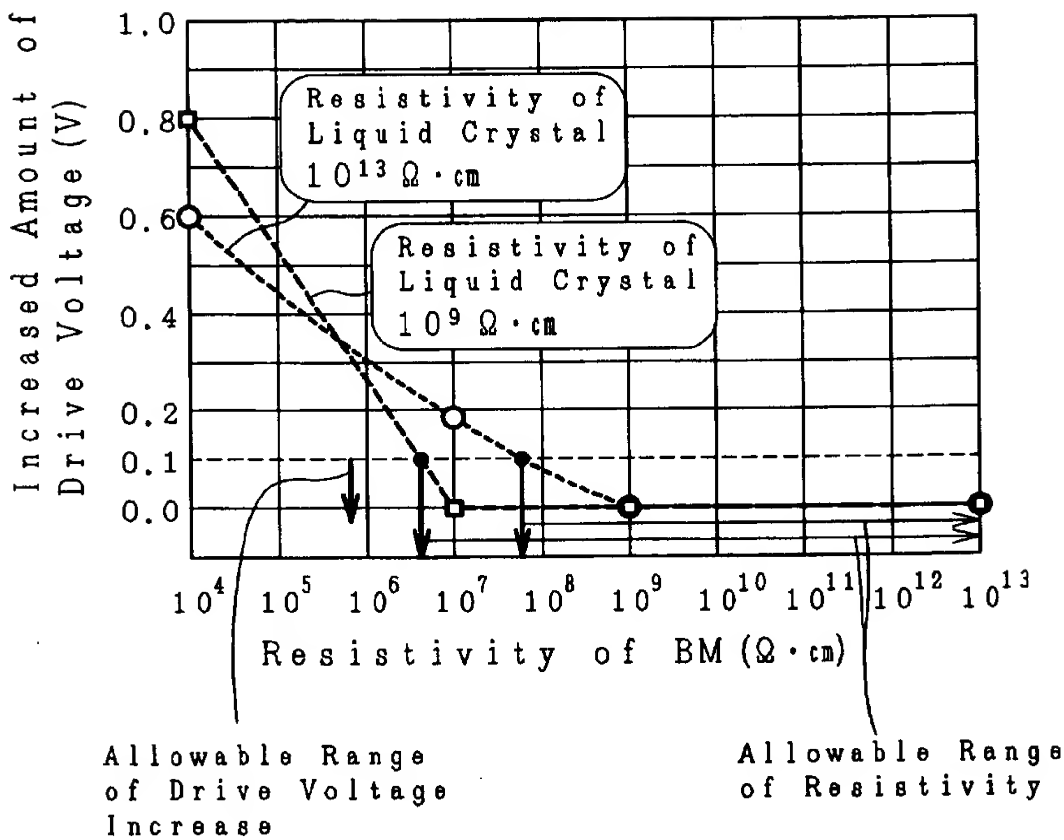

Increased Amount of Drive Voltage (V)
1.0
0.8
0.6
0.4
0.2
0.1
0.0
Resistivity of Liquid Crystal 10^{13} Ω·cm
Resistivity of Liquid Crystal 10^{9} Ω·cm
10^{4} 10^{5} 10^{6} 10^{7} 10^{8} 10^{9} 10^{10} 10^{11} 10^{12} 10^{13}
Resistivity of BM (Ω·cm)
Allowable Range of Drive Voltage Increase
Allowable Range of Resistivity

FIG. 6

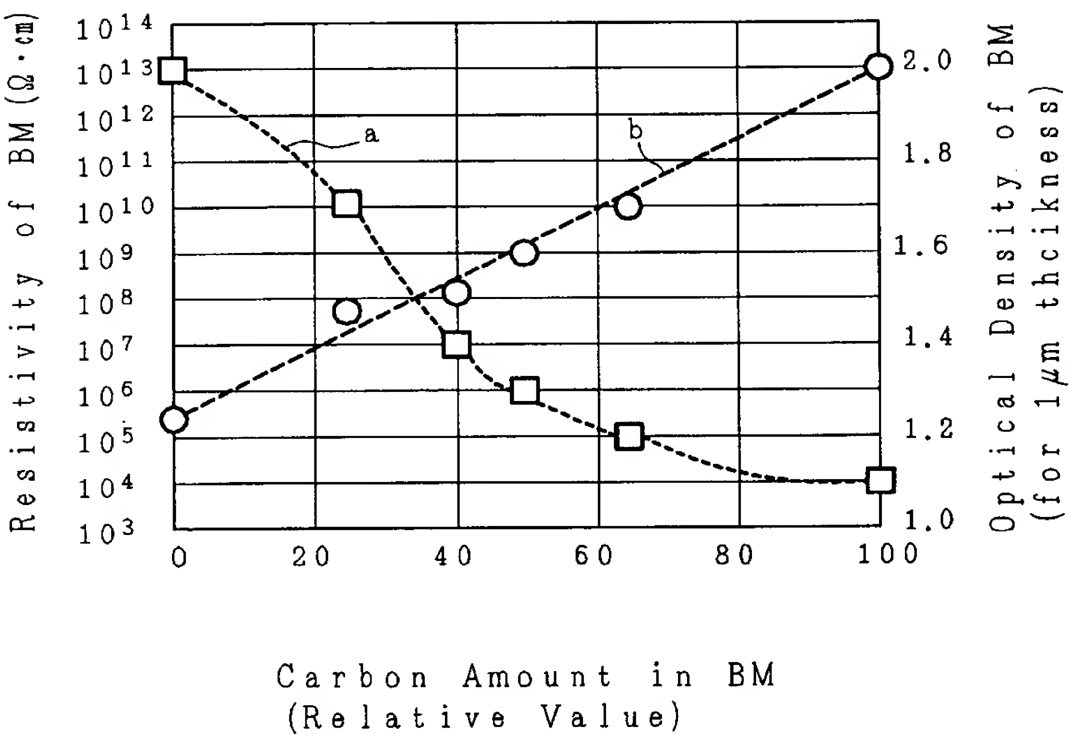

Resistivity of BM (Ω·cm)
10^{14}
10^{13}
10^{12}
10^{11}
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
10^{4}
10^{3}
a
b
2.0
1.8
1.6
1.4
1.2
1.0
Optical Density of BM
(for 1μm thcikness)
0
20
40
60
80
100
Carbon Amount in BM
(Relative Value)

FIG. 7

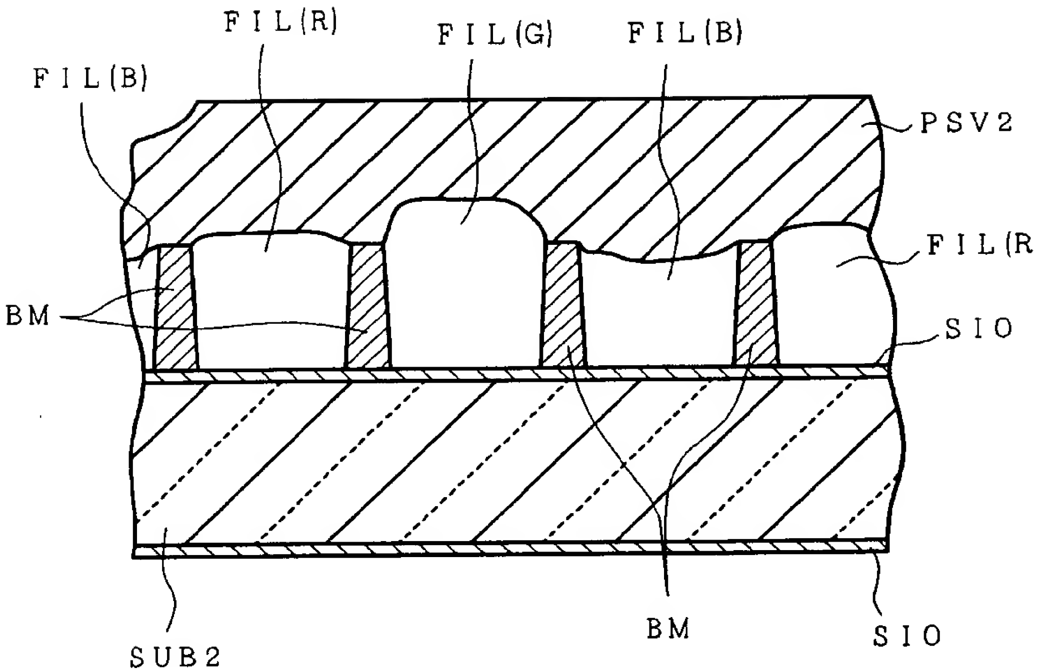


FIG. 8

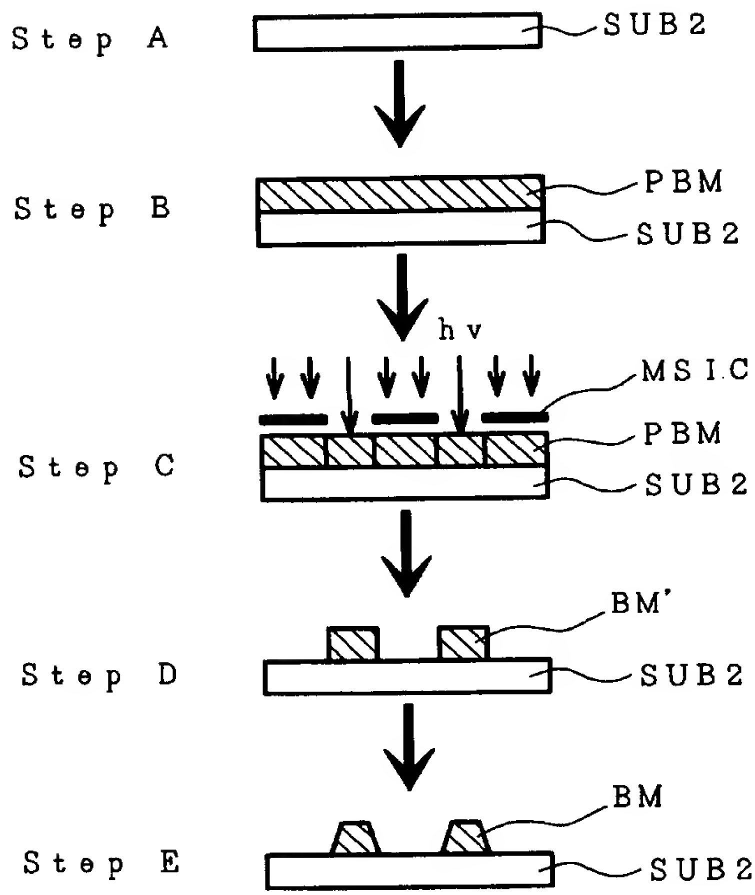

Step A
SUB2
Step B
PBM
SUB2
hv
MSIC
PBM
Step C
SUB2
BM'
Step D
SUB2
BM
Step E
SUB2

FIG. 9

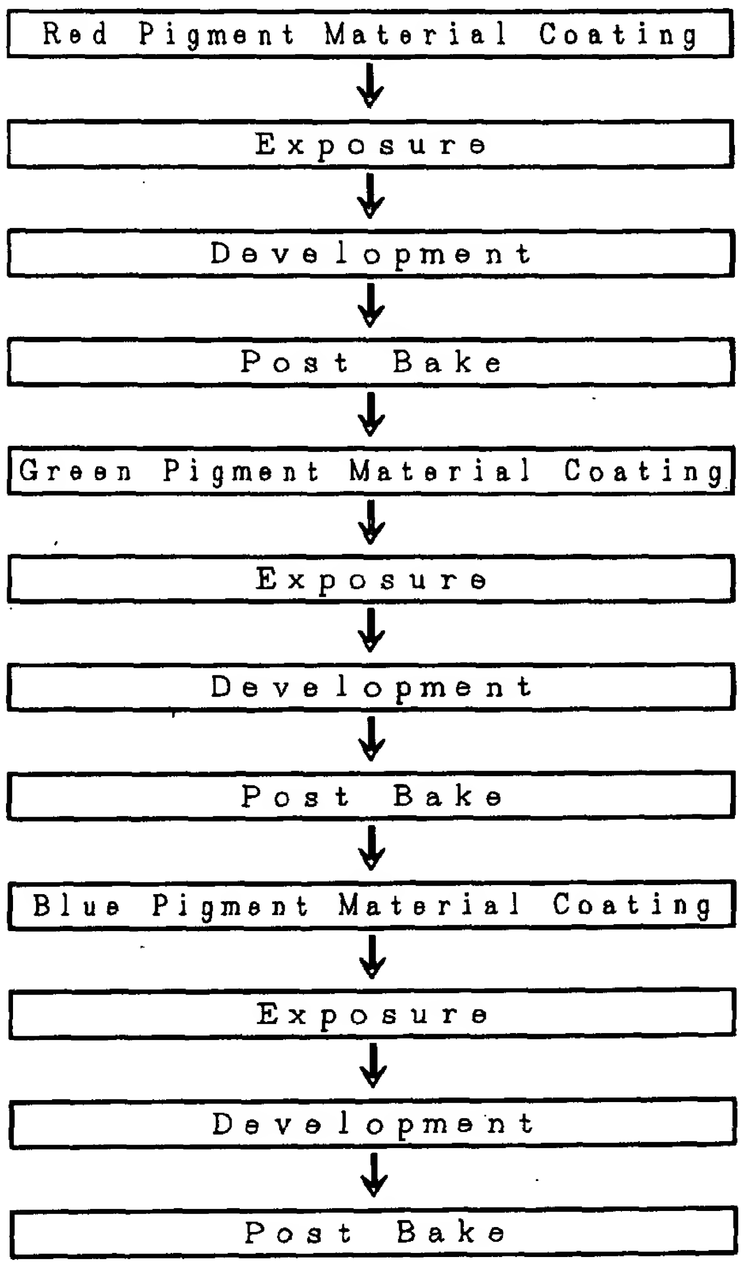

Red Pigment Material Coating
Exposure
Development
Post Bake
Green Pigment Material Coating
Exposure
Development
Post Bake
Blue Pigment Material Coating
Exposure
Development
Post Bake

FIG. 10

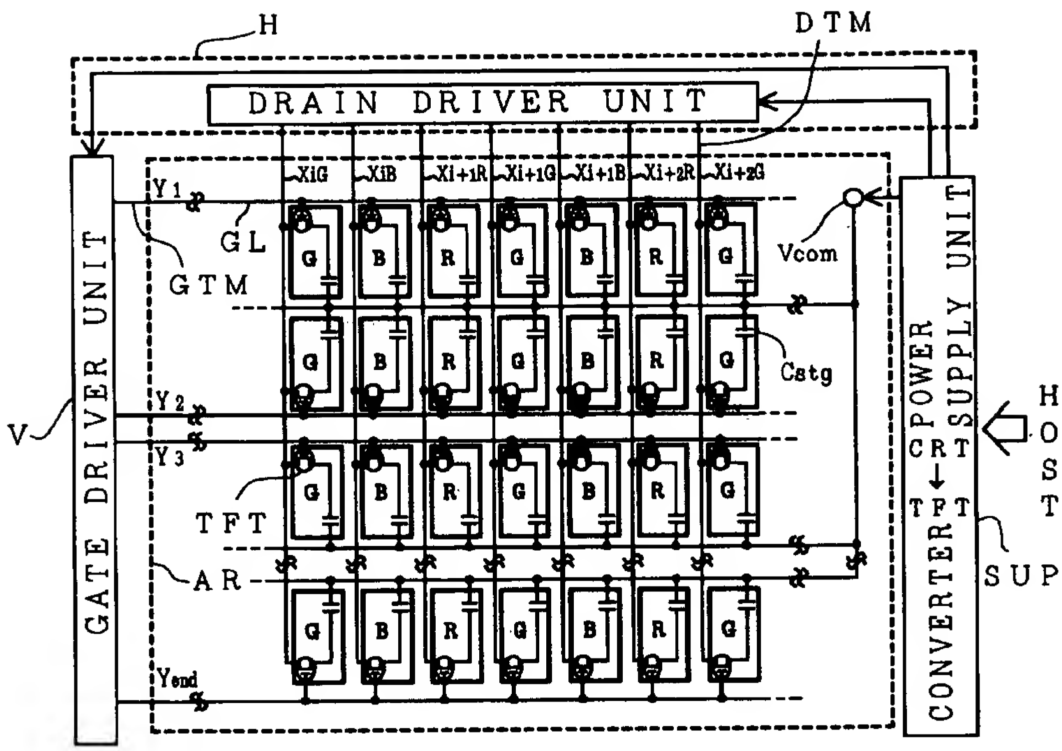

H
DTM
DRAIN DRIVER UNIT
XiG
XiB
Xi+1R
Xi+1G
Xi+1B
Xi+2R
Xi+2G
Y1
GL
GTM
Vcom
Cstg
Y2
Y3
V
TFT
AR
Yend
GATE DRIVER UNIT
POWER SUPPLY UNIT
CRT→TFT CONVERTER
HOST
SUP

FIG. 11

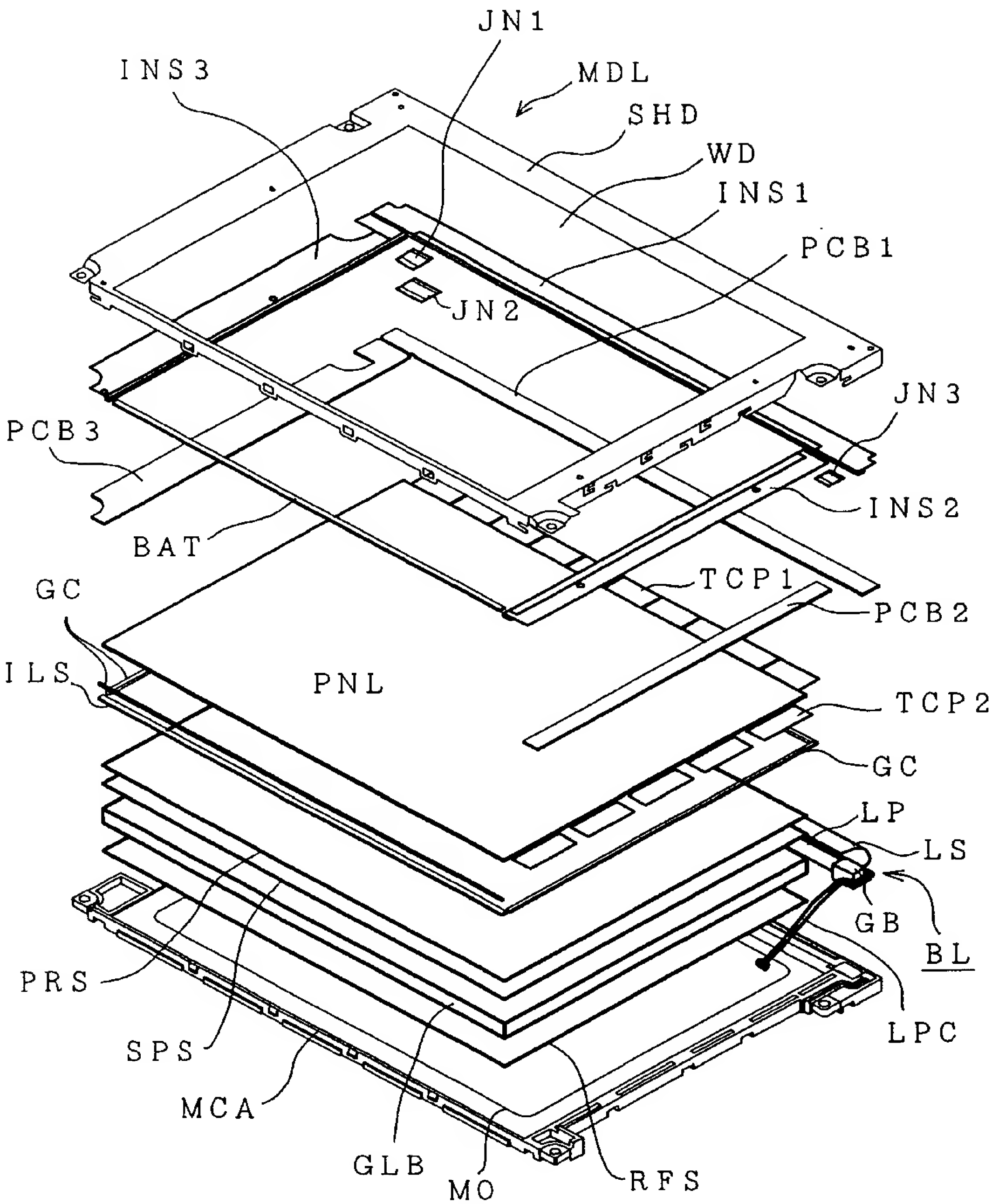

JN1
INS3
MDL
SHD
WD
INS1
PCB1
JN2
JN3
PCB3
INS2
BAT
TCP1
GC
PCB2
ILS
PNL
TCP2
GC
LP
LS
GB
BL
PRS
SPS
LPC
MCA
GLB
MO
RFS

FIG. 12

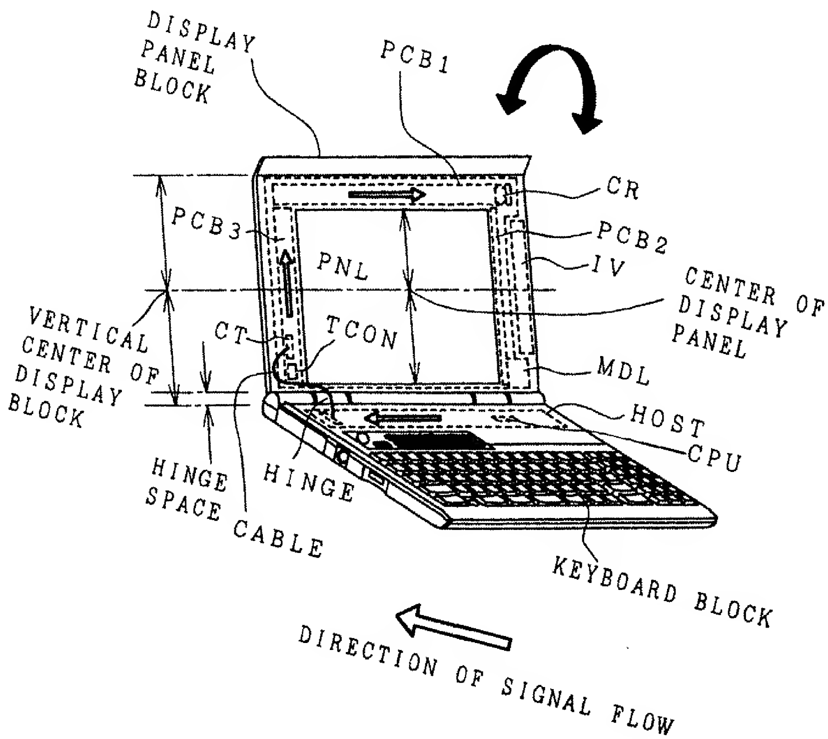

DISPLAY PANEL BLOCK
PCB1
CR
PCB3
PCB2
IV
PNL
CENTER OF DISPLAY PANEL
VERTICAL CENTER OF DISPLAY BLOCK
CT
TCON
MDL
HOST
CPU
HINGE SPACE
HINGE
CABLE
KEYBOARD BLOCK
DIRECTION OF SIGNAL FLOW

FIG. 13

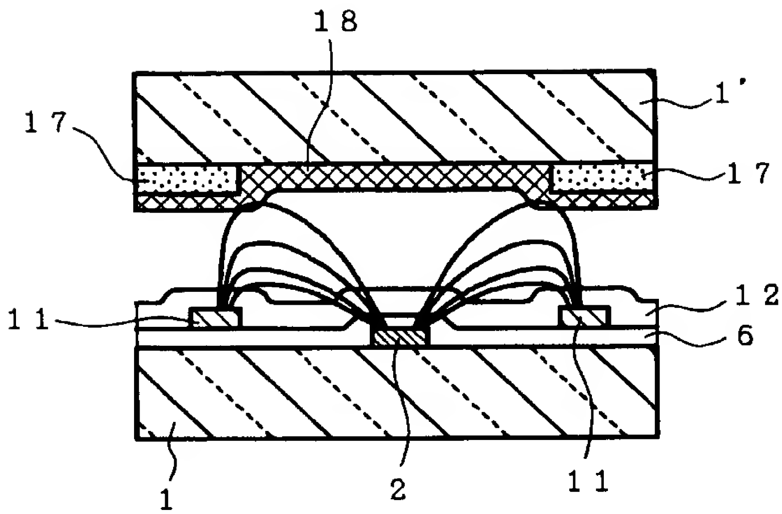


FIG. 14B

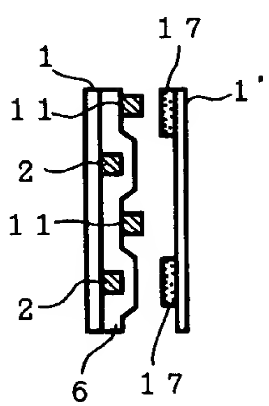


FIG. 14A

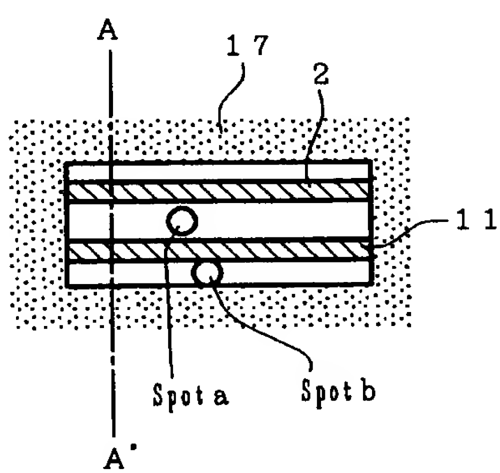
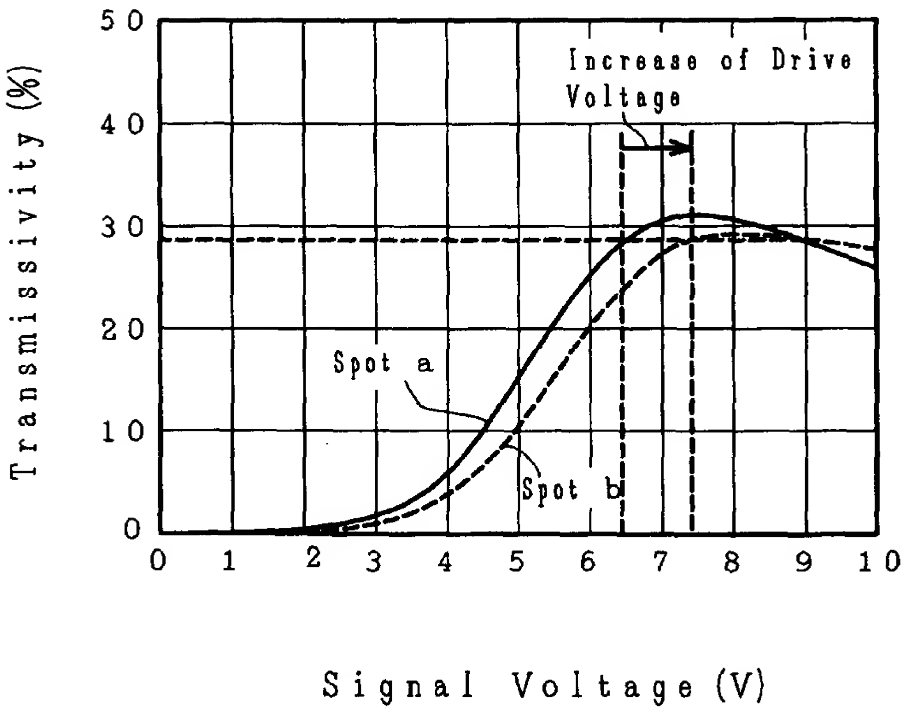


FIG. 15



Transmissivity (%)
50
40
30
20
10
0
Increase of Drive Voltage
Spot a
Spot b
0
1
2
3
4
5
6
7
8
9
10
Signal Voltage (V)

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 10 9493

Category	DOCUMENTS CONSIDERED TO BE RELEVANT Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	EP-A-0 233 056 (BREWER SCIENCE INC) 19 August 1987 * column 3, line 61 - column 5, line 59 * ---	1,3,9-11	G02F1/1335 G02F1/1343 G02B5/20 G02B5/22 G03F7/038
A	PATENT ABSTRACTS OF JAPAN vol. 017, no. 320 (P-1558), 17 June 1993 & JP-A-05 034514 (FUJI PHOTO FILM CO LTD), 12 February 1993, * abstract * ---	4,5, 7-10,12	
A	PATENT ABSTRACTS OF JAPAN vol. 016, no. 516 (P-1443), 23 October 1992 & JP-A-04 190362 (IDEMITSU KOSAN CO LTD), 8 July 1992, * abstract * & DATABASE WPI Week 9234 Derwent Publications Ltd., London, GB; AN 92-279856 * abstract * ---	4-6,8, 10-12	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
A	EP-A-0 515 225 (SHARP KK) 25 November 1992 * column 4, line 13 - column 5, line 6 * ---	1,3-10	G02F G03F
A	US-A-4 004 848 (YAMAZAKI YOSHIO) 25 January 1977 * column 1, line 40 - column 2, line 7 * * column 5, line 56 - line 60 * --- -/--	1,3	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	20 September 1996	Stang, I

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)